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Research Article

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Comparison of extraction methods to assess potassium availability for rice growing soils of canal ayacut of Kurnool district

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Summary

Eighty surface soil samples were collected from rice growing areas of Kurnool district covering eleven mandals and among them thirty samples were selected for the investigation based on K status. Among the extractants tried, the relative efficiency of K releasing extractants were in the following order of 1 N HNO_3 > Mehilich-3 > 0.2 M $NaBPh_4$ > 1 N NH_4OAc > AB-DTPA > 0.02 M citric acid > 0.01M$CaCl_2$ > distilled water. Results revealed that, highest amount of K was extracted by 1 N HNO_3 and lowest by distilled water. A pot experiment by biological Neubauer's seedling technique method was conducted to assess the releasing pattern of available K with bajra, as test crop. Among the various extractants tried, 1 N HNO_3 served as a better index of available K as it is highly positively correlated with dry matter yield and uptake with the shoot K content (r=0.353*).

Key words : Available K, Mehlich-3, NN NH_4OAc, AB- DTPA, $NaBPh_4$, Neubauer's seedling technique

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Introduction

Many chemical methods such as 1 N NH_4OAc, Mehlich-3, salts and dilute acids had been proposed by researchers for evaluation of available potassium (K) in soils (Mehlich, 1984; Soltanpour and Schwab, 1977; Srinivasa Rao and Takkar, 1997 and Mehta *et al*., 2001). The 1 N NH_4OAc method is the most widely used, but it was not suitable for soils that possess substantial amount of plant-available NEK because that the 1 N NH_4OAc method can only extract water soluble and exchangeable but not non-exchangeable K (NEK) in soils and minerals (Cox *et al*.,1999). The fertilizer scheduling in rice growing soils of Kurnool district, is done on the basis of available K in soil using NN NH_4OAc. However, there are reports indicating that N N NH_4OAc extractant fails to predict the response to potassium in illite dominated soils (Singh *et al*., 2006). Hence, an investigation was conducted on rice growing soils of Kurnool district to study the K status in relation to its short term and long term availability and to evaluate the suitability of an

extractant for available potassium in the soil for supplementing the crop with proper amounts of fertilizer K.

Resource and Research Methods

Soil collection and preparation :

Thirty surface soil samples were collected from eleven mandals of rice growing soils of Kurnool district for the study. The studied area lies between the geo-co-ordinates of N 150 08' to 150.47' and E 0780 20' to 0780 38'. The soil samples collected were air dried, ground with wooden hammer and passed through 2 mm sieve and preserved in a polyethene bag, for laboratory analysis.

Soil analysis :

The samples were analyzed for particle size analysis by Bouyoucous hydrometer method and chemical properties *viz.*, pH, EC, organic carbon, cation exchange capacity, $CaOCO_3$, available nitrogen, phosphorus and potassium were determined as per standard procedures outlined by Jackson (1973). The references used for the preparation of extractants for available potassium status are furnished in Table 2.

Potassium study

An exhaustive K depletion glass house experiment was made by using Neubauer's seedling technique as modified by Mc George (1946) was conducted on these soils using bajra as test crop to assess their K supply capacities. 250 g of soil and 250 g of quartz sand per pot was used for cropping. Hundred bajra seeds were sown in each pot. Soils were watered daily to field capacity with deionised water. The seedlings was harvested after 23 days and the K content of plants was determined after acid digestion *i.e.*, HNO_3: $HClO_4$: H_2SO_4 in the ratio of 9:3:1. The uptake of potassium per pot was arrived as detailed:

$$\frac{\textbf{Uptake of potassium by root}}{\textbf{Shoot (mg kg}^{-1}\textbf{)}} = \left[\frac{\textbf{Root}}{\textbf{Shoot dry matter in g per pot}} \times \frac{\textbf{Per cent K in root}}{\textbf{Shoot}} \times 100\right]$$

The total uptake of potassium by plant (mg kg^{-1}) was calculated by the sum of uptake of potassium by root+ uptake of potassium by shoot.

Statistical analysis :

The formulae given by Panse and Sukhatme (1978) were used for calculating the co-efficients of correlation.

Research Findings and Discussion

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Physico-chemical properties :

The studied soils exhibited a wide range of physical properties (Table 1). The soils were found moderately coarse to fine with a texture of sandy loam to clay. The pH of soils used in the study was neutral to slightly alkaline in nature and EC of most of the soils was non-saline. The soils under study were medium in organic carbon and non- calcareous in nature.

The investigated soils were low to medium in available nitrogen, whereas available phosphorus and available potassium were having medium to high status. The cation exchange capacity of the soils varied between 14.43 to 31.65 C mol (p+) kg^{-1} soil.

Table 1: Physico- chemical properties of the investigated soils

Sr. No.	Soil property	Maximum	Minimum	Mean
1.	pH	8.51	7.03	7.38
2.	EC (dS m^{-1})	1.71	0.06	0.42
3.	OC (%)	0.87	0.32	0.58
4.	$CaCO_3$ (%)	4.7	1.7	3.30
5.	Sand (%)	84.56	38.56	55.30
6.	Silt (%)	20.36	0.36	11.53
7.	Clay (%)	43.08	15.08	33.17
8.	CEC (C mol p(+) kg^{-1})	31.65	14.43	17.56
9.	Nitrogen (kg ha^{-1})	327	188	272
10.	Phosphorus (kg ha^{-1})	226	67	159
11.	Potassium (kg ha^{-1})	2343	158	737

Inorganic potassium fractions :

The available potassium was extracted with eight extractants namely distilled water, salt solutions (N.N.NH_4OAc, 0.2 M $NaBPh_4$, 0.01M $CaCl_2$), mineral acid (Boiling 1 N HNO_3), organic acid (0.01 M Citric acid) and multi nutrient extractants (AB-DTPA and Mehlich-3) to evaluate their suitability as extractant. Different extractants performed differently in extracting available potassium in the investigated soils and data are furnished in Table 2 and Fig 1.

Distilled water extractable K (Water soluble K) :

The amount of K extracted with distilled water varied from 7 mg kg^{-1} (Ramachandrapuram) to 114 mg kg^{-1} (Gajulapalli), with an average of 34 mg kg^{-1}. The distilled water extracted lower amounts of K than that of the other extractants because distilled water is the softest extractants possible (Rathore *et al*., 2000). This is in conformity with the results of Srinivasa Rao and Takkar (1997).

N.N. NH_4OAc extractable K :

Ammonium acetate is the most commonly used extractant, which extracts, both exchangeable and water soluble K. The amount of K extracted by N.N.NH_4OAc was in the range of 59 mg kg^{-1} to 872 mg kg^{-1}. The highest amount of potassium was extracted in Munagala and lowest amount of potassium is observed in Nakkaladinnae and the mean K value recorded by N.N.NH_4OAc is 274 mg kg^{-1}.

The mean soil potassium extracted by N.N.NH_4OAc was higher compared to AB-DTPA. Two extractants contains NH_4+ ion whose ionic radius is similar to K+

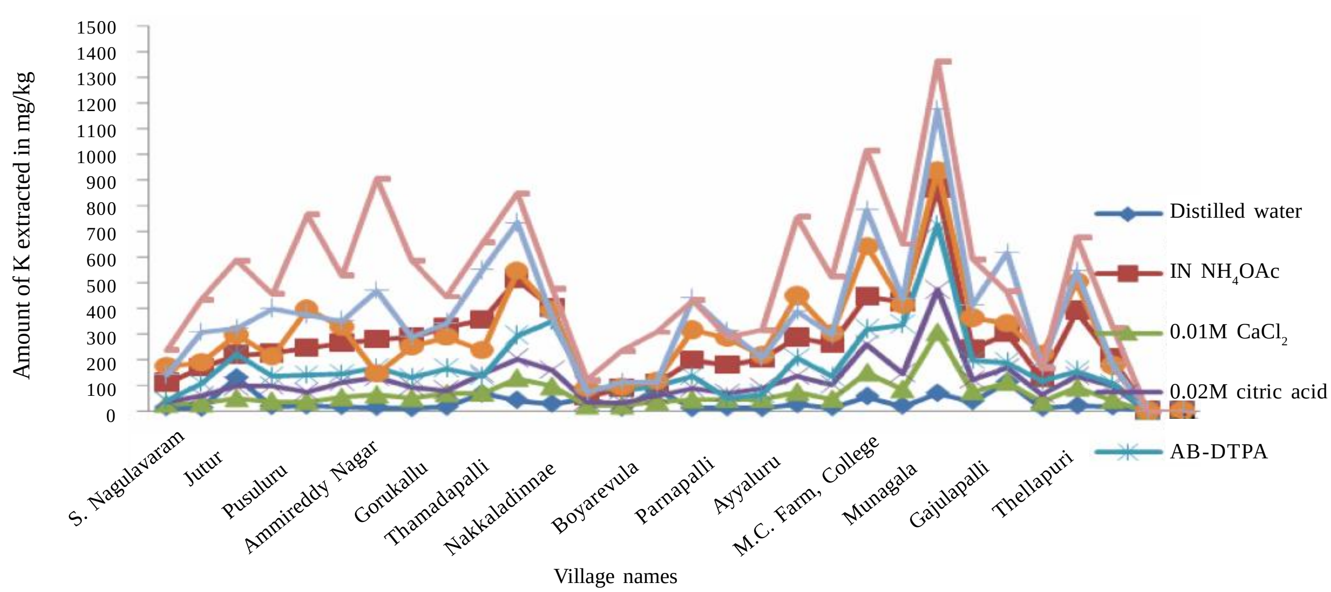

Fig. 1 : Comparative efficiency of extraction power of eight extracting egents of potassium

Table 2 : Inorganic K fractions in the investigated soils (mg kg^{-1})

Sr. No.	Extractant	References	Minimun (mg kg^{-1})	Maximum (mg kg^{-1})	Mean (mg kg^{-1})
1.	Distilled Water	Kanwar and Grewal, 1966	7	114	34
2.	1N NH_4OAc (pH 7.0)	Jackson, 1973	59	872	274
3.	1N HNO_3	Wood and Deturk, 1941	22	309	69
4.	0.02 M Citric acid	Mehta *et al*., 2001	90	940	311
5.	0.2 M $NaBPh_4$	Cox *et al*., 1999	34	476	119
6.	0.01 M $CaCl_2$	Srinivasa Rao and Takkar, 1997	123	1365	528
7.	AB-DTPA (pH: 7.6)	Soltanpour and Schwab, 1977	40	728	179
8.	Mehilich-3	Mehlich, 1984	78	1175	377

but the difference was attributed to the concentration and time of extraction. These extractants desorbs solution, exchangeable and partly non exchangeable K (Hosseinpur and Zarenia, 2012).

Boiling HNO_3 (1 N) extractable K :

The K extractable with boiling 1 N HNO_3 ranged from 123 mg kg^{-1} (Nakkaladinnae) to 1365 mg kg^{-1} (Munagala), with an average of 528 mg kg^{-1}. Among all extractants, significantly higher amounts of K was extracted by 1 N HNO_3 because in addition to exchangeable K, some of the non-exchangeable K is brought into solution by the breakdown of primary and secondary clay minerals (Ram and Prasad, 1983). The mineral acids releases more K than organic acids since mineral acids add higher H^+ activity for the same concentration and were obviously more effective in solubilising potassium from minerals which are in

Table 3: Plant growth parameters of the study

Sr. No.	Village name	Dry matter yield (g/100g oven dry soil)			Potassium content (%)		Uptake of K (mg kg^{-1})		
		Root	Shoot	Whole plant	Root	Shoot	Root	Shoot	Whole plant
1.	Ramchandrapuram	0.160	0.370	0.530	0.673	1.472	11.48	70.22	81.70
2.	Poluru	0.170	0.290	0.460	0.310	0.855	6.08	33.25	39.33
3.	S.Nagulavaram	0.150	0.410	0.560	0.958	0.674	14.99	47.07	62.06
4	Panyam Rural	0.400	0.670	1.070	0.730	1.758	32.08	161.02	193.10
5.	Jutur	0.480	0.340	0.820	0.740	1.747	39.12	72.41	111.53
6.	Allagadda Rural	0.300	0.270	0.570	0.648	1.970	21.41	59.81	81.21
7.	Pusuluru	0.170	0.370	0.540	0.813	2.060	14.62	92.00	106.62
8.	Nallagatla	0.190	0.610	0.800	0.673	1.340	13.77	119.51	133.28
9.	Ammireddy Nagar	0.350	0.810	1.160	0.670	1.009	25.88	137.81	163.69
10.	RARS, Nandyala	0.570	0.540	1.110	0.765	1.570	48.02	116.14	164.15
11.	Gorukallu	0.430	0.400	0.830	1.073	2.799	49.27	130.48	179.75
12.	Bollavaram	0.340	0.660	1.000	0.335	2.112	13.73	181.70	195.43
13.	Thamadapalli	0.460	0.590	1.050	0.658	1.319	33.67	113.75	147.41
14.	Velpanuru	0.370	0.370	0.740	0.648	0.969	26.57	51.63	78.19
15.	Nakkaladinnae	0.430	0.350	0.780	0.210	1.008	12.18	49.21	61.39
16.	Bachapuram	0.260	0.280	0.540	0.425	0.828	12.67	30.71	43.38
17.	Boyarevula	0.270	0.530	0.800	0.105	1.255	4.55	96.96	101.50
18.	Yerraguntla	0.260	0.330	0.590	0.390	2.054	11.76	79.89	91.65
19.	Parnapalli	0.310	0.800	1.110	0.660	0.709	22.53	111.88	134.41
20.	Padakandla	0.290	0.190	0.480	0.470	1.420	15.52	26.27	41.79
21.	Ayyaluru	0.240	0.480	0.720	0.625	1.393	16.44	92.70	109.14
22.	Kanala	0.370	0.250	0.620	0.765	2.012	30.92	55.07	85.98
23.	M.C.Farm, College	0.160	0.290	0.450	0.275	2.375	5.12	77.33	82.45
24.	Rayapadu	0.150	0.290	0.440	0.728	2.375	11.54	77.33	88.87
25.	Munagala	0.210	0.300	0.510	0.373	1.637	8.99	58.46	67.45
26.	Mandaluru	0.120	0.290	0.410	0.120	0.833	1.80	32.59	34.39
27.	Gajulapalli	0.190	0.270	0.460	0.935	1.963	18.76	59.61	78.36
28.	Chennuru	0.460	0.320	0.780	0.143	1.084	9.98	45.88	55.86
29.	Thellapuri	0.580	0.820	1.400	0.848	2.045	53.66	224.70	278.36
30.	Ayyavari Koduru	0.240	0.320	0.560	0.508	1.652	13.62	64.04	77.66
Control		0.080	0.190	0.270	0.090	0.916	0.72	17.40	18.12
Mean		0.303	0.427	0.730	0.576	1.543	20.02	85.64	105.66

Note: Uptake and content of potassium from different pots is exclusive of K uptake and content from the control pot

conformity with the findings of Bedi *et al*. (2002) and Laxminarayana *et al*. (2011).

Citric acid (0.02 M) extractable K :

The extraction of K with citric acid ranged from 34 mg kg^{-1} in Nakkaladinnae soil to 476 mg kg^{-1} in Munagala soil with a mean value of 119 mg kg^{-1}. Available potassium extracted by citric acid was higher than that of water soluble K and lower than 0.2 M $NaBPh_4$ and N.N.NH_4OAc. Similar findings were observed by Rao and Takkar (1997).

$CaCl_2$ (0.01 M) extractable K :

The available potassium extracted with 0.01 M $CaCl_2$ values were ranging from 22 mg kg^{-1} in the soils of Ramachandrapuram, Nakkaladinnae and Bachapuram to 309 mg kg^{-1} in the soils of Munagala with a mean value of 69 mg kg^{-1}. The potassium extracted with 0.01 M $CaCl_2$ is lower than 0.2 M $NaBPh_4$ and N.N. NH_4OAc and high compared to distilled water. Generally soils with high clay content shows high K release with dilute salt solution. Similar findings were reported by Srinivasa Rao and Takkar (1997). Lakshminarayana *et al*. (2011) also found that lowest amount of available K with 0.01 M $CaCl_2$ than that of 1N HNO_3 and 1N NH_4OAc, which may be described to its low solubilization affect on non-exchangeable and lattice K forms. Similar reports were also made by Bedi *et al*. (2002) and Hosseinpuri and Zarenia (2012).

$NaBPh_4$ (0.2 M) extractable K :

The amount of K extracted with 0.2 M $NaBPh_4$ varied from 90 mg kg^{-1} (Nakkaladinnae) to 940 mg kg^{-1} (Munagala), with an average of 311 mg kg^{-1}. The mean amount of K extracted with 0.2 M $NaBPh_4$ was lower than that of boiling 1 N HNO_3 and Mehlich-3 and higher values of potassium were recorded when compared to other extractants tested. Interlayer K, which is also the major source controlling the long term K supplying potential of soils might have been extracted by $NaBPh_4$ to give more reliable estimate of plant available K and soil K balance than 1 N NH_4OAc (Cox *et al*., 1999). Srinivasa Rao and Takkar (1997) also observed that $NaBPh_4$ extracted higher amounts of K in smectite dominated soils than 1N NH_4OAc.

AB-DTPA extractable K :

The available K extracted with AB-DTPA showed a range from a minimum of 40 mg kg^{-1} in the soils of Ramachandrapuram to 728 mg kg^{-1} in the soils of Munagala with a mean of 179 mg kg^{-1}. The mean values of AB-DTPA extracted relatively less amounts of K as compared to NH_4OAc. This was probably due to the presence of higher concentration of NH_4^+ ion in NH_4OAc than in AB-DTPA and the time of extraction. Ammonium ions are known to efficiently replace exchangeable K as well as K from specific sites (Hosseinpur and Zarenia, 2012).

Mehilich-3 extractable-K :

The amount of K extracted by Mehilich-3 was in the range of 78-1175 mg kg^{-1}. The highest value was recorded in Munagala and the lowest value was recorded in Nakkaladinnae. The mean amount of K extracted was 377 mg kg^{-1}.

On the basis of extractability of potassium, the extractants can be arranged in the following order of 1 N HNO_3 > Mehilich-3 > 0.2 M $NaBPh_4$ > 1 N NH_4OAc > AB-DTPA > 0.02M citric acid > 0.01M $CaCl_2$ > distilled water (Fig. 1).

Table 4: Inter correlations between different extracting agents

	Distilled water K	N.N. NH_4OAc K	0.01M $CaCl_2$ K	0.2 M $NaBPh_4$ K	1N HNO_3 K	0.02M citric acid K	AB - DTPA K	Mehilich- 3 K
Distilled water K	1.000							
N. N. NH_4OAc K	0.240	1.000						
0.01M $CaCl_2$ K	0.372*	0.937**	1.000					
0.2 M $NaBPh_4$ K	0.249	0.904**	0.905**	1.000				
1 N HNO_3 K	0.261	0.862**	0.808**	0.834**	1.000			
0.02M citric acid K	0.359*	0.946**	0.984**	0.897**	0.849**	1.000		
AB - DTPA K	0.347*	0.913**	0.923**	0.856**	0.780**	0.928**	1.000	
Mehilich- 3 K	0.353*	0.915**	0.917**	0.894**	0.890**	0.928**	0.818**	1.000

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Potassium study by pot culture studies :

The dry matter produced by bajra seedlings after 23 days was recorded. The mean dry matter yields of root, shoot and whole plants was 0.303, 0.427, 0.730 g per 100 g of soil. The mean dry matter of root is relatively less than the shoot. There was a wide variation in dry matter yields in different soils due to the variation in potassium supplying power of soils. Nath and Dey (1982) also observed variation in dry matter yields in the alluvial soils of Assam and in Aridisols of Rajasthan (Sharma and Swami, 2000). This can be ascribed to the variation in K supplying power of soils. The mean potassium contents of the root and shoot was 0.576 and 1.543 per cent. The mean potassium content was more in shoot than root. The mean potassium uptake by root, shoot and whole plant were 20.02, 85.64 and 105.66 mg kg^{-1}, respectively (Table 3).

Statistical analysis :

Inter correlations between different extracting agents:

The difference of potassium extracted between these methods was attributed to the concentration of extractant. These extractants desorbed solution, exchangeable, non-exchangeable and some of the lattice K. The correlation co-efficients between K extracted by these chemical methods are shown in the Table 4. All these K extractants were positively correlated with each other, though these extractants removed different quantities of K which indicates that these methods can be used for assessment of availability of K in present investigated soils and also amount of potassium extracted were comparable. Similar reports were made by Bedi *et al*.(2002).

Correlation co-efficients between different extractants, dry matter yield, K content and K uptake :

The relative efficiency of different chemical extraction methods in extracting the available potassium has been judged by working out correlation co-efficients with the potassium uptake by bajra seedlings, dry matter production and content of potassium in bajra seedlings (Table 5). A close observation of the data reveals that potassium extracted by 1 N HNO_3 serves as a better index of available potassium in the investigated soils as highly positive correlation was observed in dry matter yields of shoot (r = 0.151) and whole plant (r = 0.072) and uptake of shoot (r = 0.287) and whole plant (r= 0.263). 1 N HNO_3 also significantly positively correlated with the shoot K content (r = 0.353*). These results are in conformity with the findings of Liangxue and Bates (1990). Mehilich-3 extractable K and 1 N NH_4OAc extractable K also serves as good index of available potassium in the studied soils. The other extractants used in the study did not proved to measure the available K status in the studied soils as they showed less correlation with plant growth parameters.

Conclusion :

It showed that the amount of potassium extracted by 1 N HNO_3 serves as a better index of available potassium in the investigated soils for assessing the availability of potassium in the canal ayacut of Kurnool district soils. The next extractants proved better after 1 N HNO_3 were Mehilich-3 and 1 N NH_4OAc. However, the results will have to be confirmed by conducting field study experiments as K-exhaustion glasshouse

Table 5 : Correlation co-efficients between different extractants, dry matter yield, K content and K uptake

	Root dry matter	Shoot dry matter	Whole plant dry matter	K content in root	K content in shoot	K uptake by root	K uptake by shoot	K uptake by whole plant
Distilled water K	0.007	-0.122	-0.080	-0.128	0.147	-0.063	-0.037	-0.047
N. N. NH_4OAc K	-0.011	0.021	0.010	0.077	0.341*	0.120	0.182	0.182
0.01M $CaCl_2$ K	-0.116	-0.068	-0.104	-0.069	0.217	-0.049	0.031	0.014
0.2 M $NaBPh_4$ K	-0.095	-0.050	-0.081	0.031	0.322	0.034	0.102	0.094
1 N HNO_3 K	-0.065	0.151	0.072	0.066	0.353*	0.089	0.287	0.263
0.02M citric acid K	-0.138	-0.075	-0.120	-0.114	0.232	-0.091	0.029	0.002
AB - DTPA K	-0.120	-0.184	-0.186	-0.109	0.191	-0.081	-0.086	-0.092
Mehilich- 3 K	-0.064	0.084	0.026	0.033	0.376*	0.049	0.240	0.214

* indicate significance of value at P=0.05

experiment involved small volumes of soil that were intensively exploited by roots and the removal of plant tops ensured that there was limited recycling of K. Under field conditions plant roots can exploit a much larger volume of soil and recycling of K from foliage can occur. Furthermore, under tropical climate the weathering process can promote the release of K from K-minerals.

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